Ash Content of Loblolly Pine Wood As Related to Specific Gravity, Growth Rate, and Distance from Pith

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ABSTRACT. In earlywood of *Pinus taeda* L. grown in central Louisiana, ash content generally decreased with increasing distance from the pith and increased with increases in rate of tree growth (as measured in rings per inch). Latewood ash content was unrelated to the gross wood factors of distance, from the pith, specific gravity, and growth rate. The ash content of earlywood was higher (average 0.430 percent) than the ash content of latewood (average 0.389 percent).

THE WOOD IN A LARGE second-growth southern pine stem characteristically increases in specific gravity with increasing rings from the pith, while the growth rate slows. For a given number of rings from the pith, however, the variation between stems in specific gravity and growth rate is remarkably large. For example, it is possible to isolate corewood of low density and slow growth from one stem, while corewood from a second stem may also be of low density but of fast growth. As another example, the outer wood of one stem and the corewood of a second stem may both contain fast-grown wood of low density.

In the research reported here, the ash content of the earlywood and latewood of loblolly pine was analyzed in relation to three gross wood characteristics that can be measured readily. The characteristics, or factors, wer rings from the pith, growth rate, and specifi gravity. By removing wood from many stem and stratifying it by two densities and tw growth rates at each of three radial position in the stem, it was possible to isolate th independent relationships of each wood cha acteristic with ash content.

This approach is quite different from th taken in studies where it is desired to dete mine the radial variation of wood characte istics in stems. In such research, the variatio usually is measured along sections, wedges, increment cores removed from the stem. Th typical change in specific gravity and growt rate along the sections precludes stratificatic by specific gravity and growth rate at a radial positions, and therefore the independe relationship of each factor with such woc characteristics as ash content is confounde

Because of the method of sampling, ar because the sample was limited to wood fro trees in central Louisiana, the present resul are not necessarily representative of tl species *Pinus taeda* L. Nevertheless, if the a content of wood can be predicted from gro

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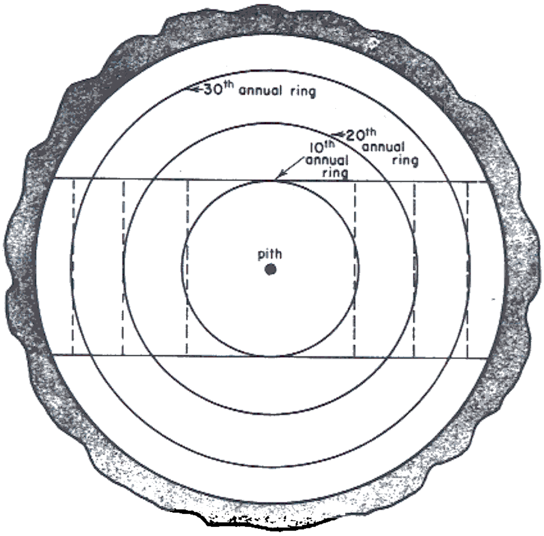

Figure 1. Method of log breakdown.

factors, industry may be able to apply the information. For example, ash content is an indicator of the amount of trace elements in the wood. These elements are important in such processes as pulp bleaching (1). Since the ash content of chips from pine veneer cores may differ considerably from that of chips made from slabs and edgings taken from the periphery of a large saw log, modification of the bleaching operation may be desirable when the raw material source can be identified.

Procedure

Fifty trees in a stand near Alexandria, La., were field-identified as loblolly pine and felled during August. Portions of the stems that exhibited 40 annual rings or more were bucked into 8-foot lengths, and the top end of each length was marked (Fig. 1). Logs with visible defects, such as compression wood and decay, were discarded.

The logs were then slabbed to a pith-center cant which was ripped along the 10th, 20th, and 30th growth increments to form five boards. Boards were stored underwater to prevent sap stain and moisture loss. The specific gravity (ovendry weight and green volume) and growth rate were determined on a 1-inch sample cut from the midpoint of each board; removal of this sample reduced the boards to 4-foot lengths. On the basis of these preliminary measurements, 200 pounds of wood were selected for each of two replications (blocks) in each category of the factorial design outlined below. Boards having specific gravities and growth rates near the category division points were rejected.

Variables in the design were:

1) Unextracted specific gravity (ovendry weight and green volume)
   (a) Less than 0.49
   (b) More than 0.49
2) Growth rate
   (a) Less than six rings per inch
   (b) More than six rings per inch
3) Rings from the pith (position in tree)
   (a) 0 to 10 (corewood)
   (b) 11 to 20 (middle wood)
   (c) 21 to 30 (outer wood)

Sample boards in each block and each category were separately reduced to chips that averaged somewhat less than 1 inch in length. A random subsample of 1,000 chips was then taken from each of the 24 samples for measurement of physical properties. Chips were stored in capped jars at 4°C.

Specific gravity (for use in subsequent analysis) was measured on 500 of the subsample chips; the method was that described by Smith (2). Specific gravity of extractive-free wood was calculated by reducing the ovendry weight of chips by the weight of the alcohol-benzene extractive content of a matched sample; TAPPI Standard Method T 6 os-59 was used.

Growth rate in rings per inch could not be determined from chips. It was therefore measured prior to chipping on the samples used for segregating the boards. Because boards had variable cross-sectional areas, measurements were weighted by area in calculating the mean growth rates, which were then considered representative of the chips in each replication.

Ash content was determined on 200 chips randomly selected from each 1,000-chip sample. The selected chips were air-dried, dissected into earlywood and latewood fractions, and separately ground in a Wiley mill to pass a 40-mesh screen.

Approximately 1 g of the resulting meal (ovendry basis) was transferred to a clean, tared crucible. The crucible and meal were dried for 12 hours at 105°C., and the ovendry weight of meal was then determined to the nearest 0.01 mg. Five milliliters of concentrated nitric acid were pipetted into the crucible in 1-ml steps and the sample allowed to nitrate to dryness on a hotplate.

The resulting partially decomposed ash was placed in a muffle furnace at room temperature. The temperature was slowly increased over a 1/2-hour period to 475°C. and maintained for 6 hours. After the crucible and ash had cooled for 1 hour in a desiccator containing phosphorus pentoxide, the ovendry weight of ash was determined to the nearest 0.01 mg. Ash content was expressed as a percentage of the ovendry weight of wood. This procedure was replicated three times for each of the 48 samples and the average taken as the ash content.

The ashing procedure outlined previously was selected (after preliminary experiments) because it gave accurate and consistent results with the quantity of meal used and because it minimized the loss of certain volatile metallic compounds during incineration of the nitrated meal.

Results

Table 1 summarizes the results of the wood-property and ash-content determinations for each wood category of each block. As expected, gross wood properties exhibited a wide range of values and reflected the method of specimen preparation. Chip specific gravity ranged from 0.421 to 0.633 for unextracted wood, and from 0.396 to 0.616 for extracted. Growth rate ranged from 4.11 to 12.39 rings per inch. The averaged values for ash ranged from 0.342 to 0.548 percent for the earlywood, and from 0.282 to 0.478 percent for the latewood.

Table 2 lists mean ash contents according to unextracted chip specific gravity, number of rings from the pith, rings per inch of growth rate, and cell type. By variance analysis, ash contents differed significantly with changes in the level of each primary variable except growth rate and chip specific gravity.

Table 1. — RESULTS OF WOOD PROPERTY ANI ASH CONTENT DETERMINATIONS.[1]

Rings from pith	Specific gravity[2] Unextracted	Specific gravity[2] Extracted	Rings per inch	Ash content Earlywood (%)	Ash content Latewood (%)
		— Block 1 —			
0-10	0.430	0.401	4.75	0.437	0.445
0-10	.447	.418	10.13	.488	.442
0-10	.497	.446	4.47	.481	.341
0-10	.526	.465	12.39	.466	.366
11-20	.443	.413	5.52	.468	.347
11-20	.497	.470	6.84	.464	.282
11-20	.523	.503	4.78	.548	.443
11-20	.548	.520	8.34	.411	.439
21-30	.469	.455	5.21	.352	.373
21-30	.446	.431	8.15	.378	.332
21-30	.512	.485	6.30	.344	.446
21-30	.527	.503	9.86	.429	.401
Average	.489	.459	7.23	.439	.388
		— Block 2 —			
0-10	.421	.396	4.11	.480	.421
0-10	.454	.417	7.59	.446	.346
0-10	.501	.446	4.80	.394	.333
0-10	.502	.431	11.83	.442	.447
11-20	.447	.411	5.53	.403	.368
11-20	.449	.433	7.08	.497	.375
11-20	.532	.509	5.30	.404	.351
11-20	.524	.484	12.38	.521	.478
21-30	.446	.429	4.91	.359	.388
21-30	.442	.431	8.27	.415	.468
21-30	.633	.616	5.53	.342	.318
21-30	.521	.507	8.27	.360	.386
Average	.489	.459	7.13	.421	.390

[1] Each numerical value of ash content is the avera of three observations. Specific gravity and rin per inch are based on one observation.
[2] Based on ovendry weight and green volume.

Table 2. — EFFECT OF STUDY VARIABLES (LOBLOLLY PINE ASH CONTENT.[1]

Factor	Ash contei (%)
Unextracted chip specific gravity	
Less than 0.49 (avg. 0.45)	0.407
More than 0.49 (avg. 0.53)	.412
Number of rings from pith	*
0-10 (core)	0.423
11-20 (middle)	.425
21-30 (outer)	.381
Rings per inch	
Less than 6 (avg. 5.1)	0.399
More than 6 (avg. 9.3)	.420
Cell type	*
Earlywood	0.430
Latewood	.389
Grand mean	0.410

[1] All factors were tested at the 0.05 level; signific differences are indicated by *.

For all specific gravities, numbers of rings from the pith, and growth rates, the ash content of earlywood was significantly higher (0.430 percent) than the ash content of latewood (0.389 percent).

For all specific gravities, growth rates, and cell types, ash averaged 0.423 percent for corewood, 0.425 percent for middle wood, and 0.381 percent for outer wood. By Duncan's multiple range test, the value for outer wood was significantly different from values for core and middle wood.

The interaction of number of rings from pith and cell types was significant at the 0.05 level.

Number of rings from pith	Ash content for two cell types (%)	
	Earlywood	Latewood
0-10 (core)	0.454	0.393
11-20 (middle)	0.465	0.385
21-30 (outer)	0.372	0.389

An inference from this tabulation is that the ash content of earlywood from the outer portion of the stem is lower (0.372 percent) than the ash content of earlywood from the middle wood or the corewood (0.465 and 0.454 percent, respectively). No differences in latewood ash content were detected by the multiple-range test or variance analysis.

To clarify the interaction, the variables were related to ash content of earlywood and latewood by stepwise multiple regression. Equations were developed by introducing the independent variables in decreasing order of their individual contribution to the cumulative R^2. Equations were of the type

$$y = b_0 + b_1x_1 + b_2x_2 + \ldots,$$

where y is the dependent variable, *e.g.*, ash content of earlywood or latewood; b_i, a regression coefficient; and x_i, an independent variable, *e.g.*, rings from the pith, chip specific gravity, or rings per inch of growth rate. The values used for rings from the pith were midpoints: 5, 15, and 25. The individual variables and their interactions were considered. The equations were tested at the 95-percent level of probability, and all variables are significant at that level.

Correlations between independent variables were low ($r < 0.45$). The factorial design avoided certain correlations that exist in a tree stem. For example, the correlation coefficient between chip specific gravity and number of rings from the pith was 0.23 because wood of both high and low gravity was considered at all positions. Hence the use of all independent variables in a single regression equation is statistically valid.

As indicated by the analysis of variance, the ash content of latewood proved unrelated to any study variable.

By regression analysis, earlywood ash content proved independently related to the square of number of rings from the pith and the product of number of rings from the pith and rings per inch of growth rate:

$$A_{ew} = 0.45013 - 0.00028(NR)^2 + 0.00059(NR)(RI) \qquad 1$$

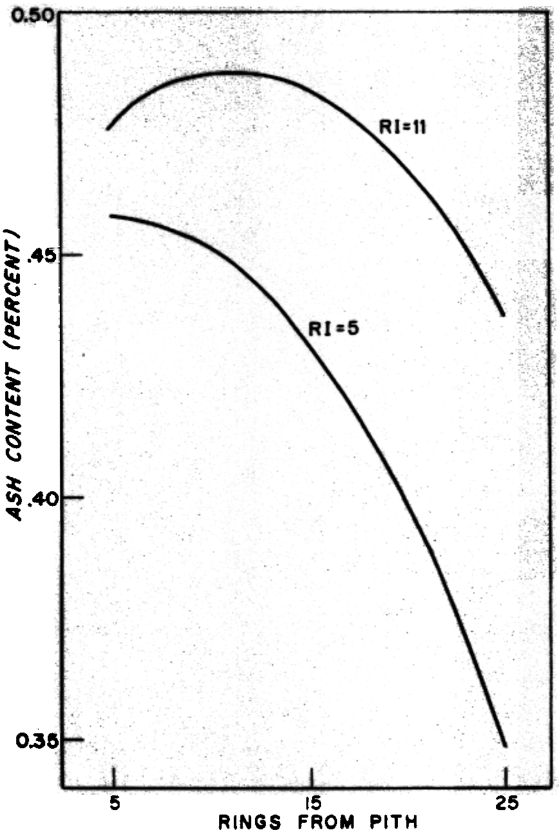

Figure 2. — Earlywood ash content as related to number of rings from the pith and rings per inch of growth rate.

where

A_{ew} = earlywood ash content in percent
NR = number of rings from the pith
RI = rings per inch of growth rate

The equation accounted for 56 percent of the total variation in ash; the standard error of the estimate was 0.040.

Figure 2 charts the relationship of earlywood ash content to rings from the pith at two growth rates. The graphed lines were obtained by substituting a range of values for the variables on the X-axis and fixing the remaining variables in the regression equation at the values indicated.

When the growth rate was slow (11 rings per inch), earlywood ash increased slightly with increasing distance from the pith for the first 12 rings, then decreased. For wood of fast growth (five rings per inch), earlywood ash decreased with increasing rings from the pith; the rate of decrease became greater with increasing number of rings. For any given number of rings from the pith, earlywood ash content increased with increasing rings per inch of growth rate (Eq. 1). Thus, high earlywood ash is associated with core or middle wood of slow growth, while low earlywood ash is characteristic of fast-grown, mature wood.

The various combinations of number of rings from the pith and growth rates that result in the highest earlywood ash content can be precisely determined for this particular sample and equation. By setting the first derivative of Equation 1 with respect to number of rings from the pith (NR) equal to zero we have:

$$\frac{\partial A_{ew}}{\partial NR} \quad -0.00056(NR) + 0.00059(RI) = 0$$

and

$$NR \quad 1.0535142(RI) \qquad (2)$$

Since the second derivative is negative, a maximum value for earlywood ash content is obtained for values of rings from the pith (NR) and rings per inch (RI) satisfying Equation 2. For example, the following combinations of RI and NR give maximum ash:

RI	NR
4	4.21
6	6.32
8	8.42
10	10.54
12	12.64

Discussion

This research has considered the ash contents of loblolly pine wood obtained from logs displaying more than 40 rings. Although the proposition was not tested, it seems possible that ash content of wood may vary with age of the tree as distinct from age of the wood within the tree. For example, the ash content of corewood from plantation trees grown on a short rotation may differ considerably from the ash content of corewood obtained from a mature natural stand. It is also probable that geographic area of growth (and possibly season of felling) will affect ash content.

The technique of chip sampling appears to permit efficient sampling of large quantities of wood without loss of between-sample variability, provided that more than one sample block is used. The technique may also be useful in measuring wood quality in whole trees. For example, cross-sectional disks of uniform thickness could be cut at several equally spaced heights up the bole, and the ash content, chemical constituents, and morphological properties could be determined from chips made from the disks. Thus, the measurements would be automatically weighted for changes in the volume of wood with increasing height in the tree.

Literature Cited

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